BY DANIEL WOJTKOWIAK, RADIO FREQUENCY SYSTEMS

Preventing microwave interference

Wind and other environmental influences play a major role in signal distortion

Over the past decade microwave links have proved to be a popular solution for the telecommunications industry. The relative ease and economy of their installation has fueled their deployment in an increasing number of point-to-point and point-to-multipoint applications—from communications backbones to branch links and distribution networks—in addition to applications in the broadcast industry and in private enterprises. With the rise of new cellular operators and new technologies, overall microwave network density is undeniably escalating.

However, the escalation of microwave communications has created new challenges. The greater the number of point-to-point links in a given area, the greater the potential they will interfere with one another. Because any distortion of the signal reduces the quality of service, controlling interference is now the mandate of any radio network operator and national regulatory authority. A good starting point for eliminating, or at least reducing, interference is the design and location of the signal source—the microwave antenna.

Figure 1 shows a typical radiation pattern of a microwave antenna. This example shows the main beam at 0 degrees, plus side lobes that are significant to about ±90 degrees from the main beam. The side lobes can cause interference with adjacent point-to-point links and consequently must be minimized through careful antenna design and installation.

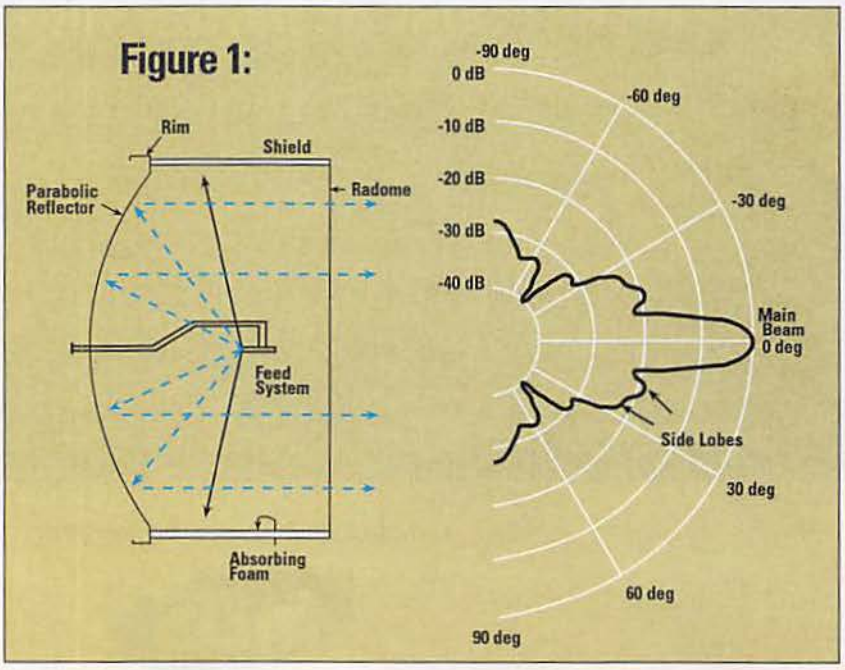
Radomes are used for two primary applications in radio-link antenna design. The first is to cover the antenna-feed system to protect it from the elements. In addition, a radome significantly reduces the wind load of an antenna system by preventing the dish and shield from "catching" wind. However, both radome material and thickness need to be carefully considered to optimize the power transmitted through the radome, while at the same time ensuring the side lobes are not increased to detrimental effect.

Figure 2 shows a plot of the reflection characteristics at a plane-wall radome for different materials. Each of these materials are characterized by a relative dielectric constant of $\epsilon_r = 2$; however each material has a different loss parameter, tan δ, where tan δ ranges from 0.0018 (low loss) to 18 (high loss). Figure 2 shows that for low-loss materials, there exists two distinct minimum values of the reflection coefficient, for which a radome wall will allow maximum transmission of incident power. These correspond to design values where the ratio of radome wall thickness (d) to microwave wavelength in the sheet (λ) is close to either zero or 0.5.

The first case of $d/\lambda \approx 0$ is practically realized as $d < \lambda/10$ and leads to flexible radome materials with typical thicknesses of 0.4 to 0.6 millimeters—essentially as thin as is practical. Flexible radomes are commonly used for larger antennas (greater than 4 feet), to avoid the bulk and weight of solid radomes.

The second design case of $d/\lambda \approx 0.5$ is more complex, and leads to the design of solid radomes, which are more economical to produce at the smaller sizes (less than 6 feet). The practical implication of $d \approx \lambda/2$ is that the thickness of solid radomes is always dependent on the wavelength (and hence frequency) to be used in the application. Assuming a dielectric constant between 2.5 and 3, typical solid radome thicknesses for selected frequencies would be as follows: 6 mm (14 GHz), 4

Figure 1:



mm (22 GHz), and 2.4 mm (38 GHz).

It is important to note that if a radome of incorrect thickness is used, the transmitted power will be reduced, and consequently the antenna gain also reduced. Greater radio power would then be required to achieve the desired radiation power, resulting in a corresponding increase of side lobe radiations. This illustrates the fact that correct radome design is critical not only for optimizing link budget, but also for interference control, since an increase in side lobe radiations would raise the potential for interference.

Figure 2 is valid for the "ideal" case, where wave fronts hit the wall perpendicularly. Now consider the situation for signals not having this ideal orientation. Given the longer effective wave path through the radome material as they hit the wall obliquely, the optimum thickness is now also dependent on the angle of incidence (θ), measured as the deviation from normal.

In practice, however, angles of incidence of up to 20 degrees have negligible effect on the optimum radome thickness. This is illustrated for flexible radome materials in Figure 3, which shows the relationship between angle of incidence (θ) and $d/\lambda o$ (where λo is the free space wavelength) for achieving 95% power transmission through materials with different dielectric constants. For values of θ up to 20 degrees, the optimum thickness is barely impacted—particularly for low-loss materials, which should be those considered for radome design purposes.

A similar relationship holds for solid radomes. A small degree of tilt in the main beam—about 5 degrees—actually *improves* the performance of the antenna, by directing spurious reflections within the antenna away from the microwave feed system.

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The influence of typical thin-wall or flexible radomes can be seen in Figure 4, which compares the radiation patterns—with and without radomes—of microwave antennas operating at 6.4 GHz and 33.4 GHz. At 6.4 GHz it is evident the radome has negligible effect on the radiation pattern. However, at 33.4 GHz the gain of the antenna is decreased by 1 dB due to attenuation by the radome. Once again, to achieve the same link budget, the radio power has

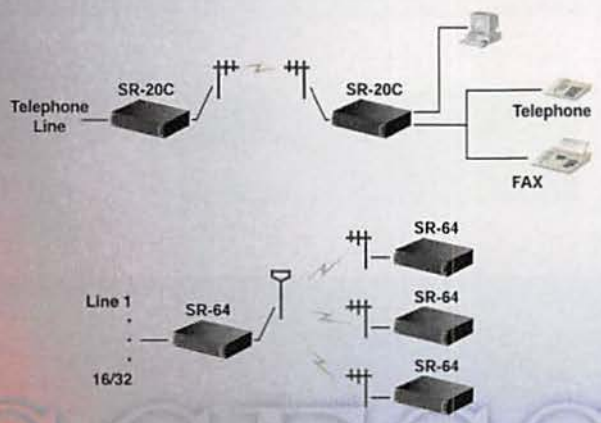

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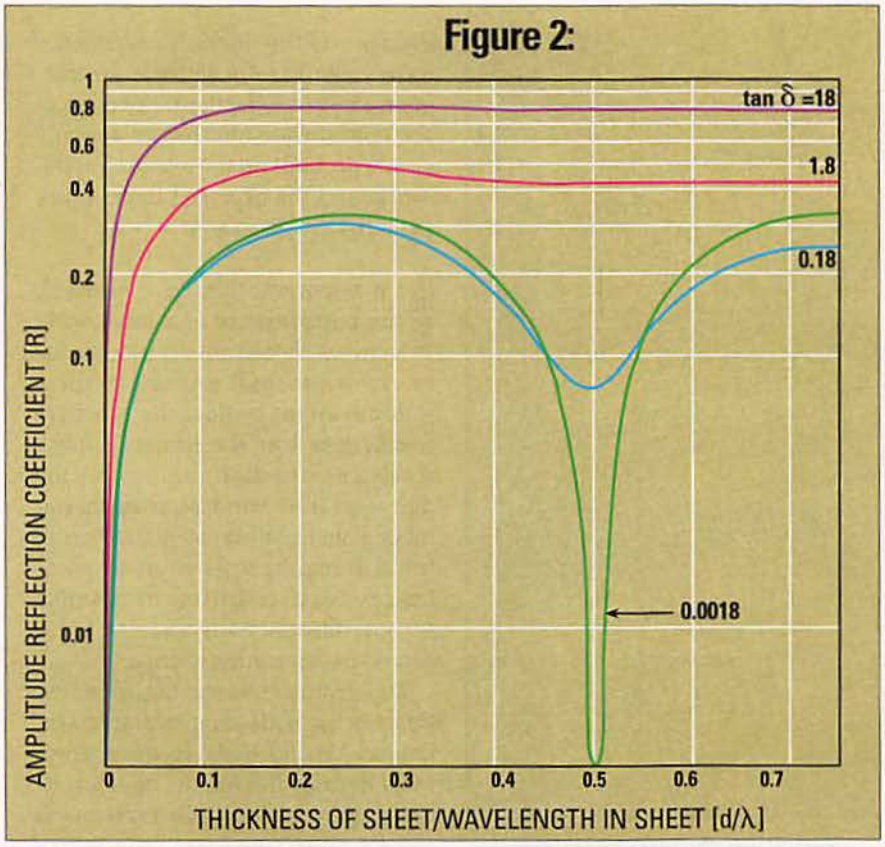
Figure 2:



to be increased by 1 dB, causing a higher interference potential outside the main beam. The presence of the radome also leads to increased side lobe levels, clearly visible in Figure 4 at azimuth angles between 20 and 60 degrees.

This effect of the radome on the 33.4 GHz antenna is because flexible radome design becomes more sensitive, at higher frequencies, to the practical constraints on material thickness and stability. Whereas the design ratio of $d/\lambda \approx 0.01$ can be achieved for the 6.4 GHz antenna, the best possible case for the 33.4 GHz antenna is just $d/\lambda \approx 0.05$, which is not as close to the ideal zero.

No matter how carefully a microwave antenna radome is designed, the potential increase in side lobes remains. This must be taken into account during other aspects of design and installation to minimize interference.

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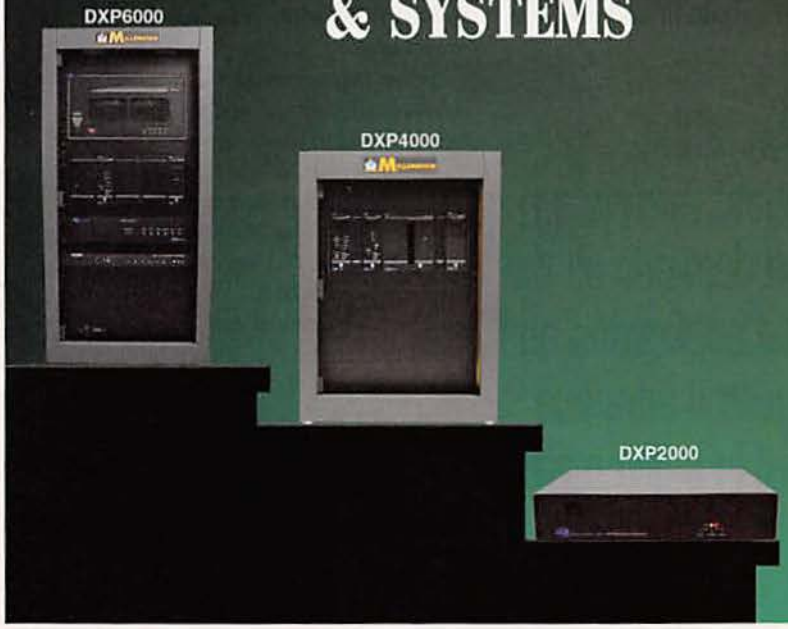

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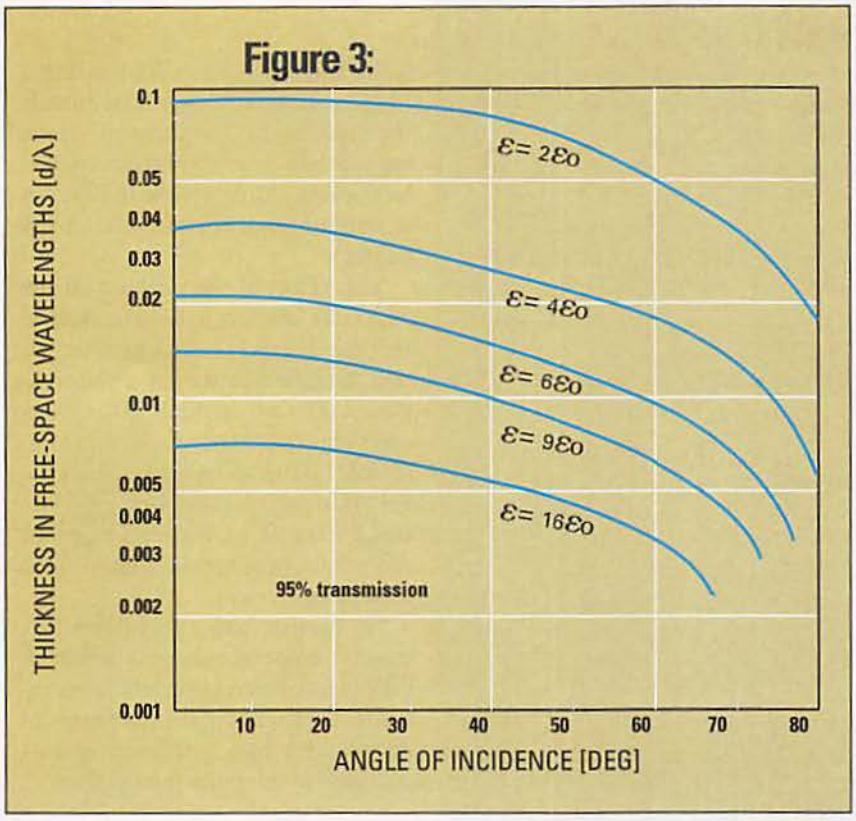

The standard-performance microwave antenna consists of an open dish and a feed system. Usually lacking a radome (although a molded radome is an option), standard-performance antennas are economical solutions for specific applications. Aside from the lack of environmental protection of the feed system, the main drawback is the diffraction of microwave power at the rim of the dish, resulting in significant backward reflections at azimuth angles of ±100 degrees that can seriously interfere with adjacent point-to-point links.

To literally block these backward rim reflections, antenna designers place a shield around the circumference of the antenna, to which a planar radome is usually attached. These "high-performance" microwave antennas may be further enhanced by the application of an absorbing foam to the inside of the shield, resulting in "ultra-high-performance" microwave antennas. The foam absorbs spurious reflections within the antenna and dramatically improves performance by limiting the side lobes.

Radiation-pattern envelopes for standard-, high-, and ultra-high-performance antennas are compared in Figure 5. The improvement in side lobe-reflection control of the ultra-high-performance antenna over both other antennas is evident.

Interestingly, though, the high-performance antenna exhibits poorer performance than the standard-performance antenna between 20 and 60 degrees—the result of additional reflections off the shield. It nevertheless proves significantly better at preventing backward reflections. Selection of the appropriate microwave antenna clearly depends on the intended application and the expected interference potential in a given area.

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It is important that, once installed, the performance of a microwave network should not deteriorate due to environmental impact. While a radome might protect the sensitive feed system from the elements, only a stable construction can protect the dish itself from wind. Mechanical stability of an installed antenna is critical for it to maintain its point-to-point link, as well as restricting its potential for interference with adjacent links, should its orientation change.

Different antenna manufacturers use different methods of rating antenna resistance to wind. Radio Frequency Systems defines the operational windspeed rating of an installed antenna as that for which temporary deflection of the main beam is within one-third of the half-power beam width of the antenna. (Half-power beam width is defined as the angle, relative to the main beam axis, between the two directions at which the measured co-polar pattern is 3 dB below the value on the main beam axis.) Within this operational wind speed—of which typical values are 120 to 140 miles per hour—the point-to-point link will be satisfactorily maintained.

Other standards consider the operational wind speed as that for which the main beam is not deviated by more than 0.1 degree. Whatever the method used, it is important to take the deflection of the mounting structure into consideration during calculation of the beam deflection.

The positional mounting of antennas must also be considered by operators seeking to minimize interference. Typical multi-antenna tower installations, with their many side lobe radiations, are a breeding ground for interference. In other cases, the mounting structure may directly impact the performance of the microwave link

through shielding and the generation of reflections from outside of the antenna itself; this is particularly true when antennas are mounted on the face of buildings and solid towers. Significant reflections could arise when an antenna is mounted too close to a solid structure to the side. Such structure-generated reflections are likely sources of interference, and often are not taken into consideration by operators during installation.

Managing interference is not a new issue, but it has certainly become more critical as the prevalence of radio networks has grown. Judicious antenna selection, design and installation is more essential than ever to minimize the interfering effect of spurious emissions, and to maximize performance of the microwave link network. ■

Daniel Wojtkowiak is global product manager, vice president-microwave antenna systems for Radio Frequency Systems. He holds a doctorate in engineering based on his studies of multi-frequency radar. He joined RFS kabelmetal in 1989, and in 1993 became head of the engineering group responsible for the development of radio-link antenna and passive waveguide components. In 1999 he became product manager-microwave antenna systems, responsible for Radio Frequency Systems' European region, and in 2003 was appointed to his current position.

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Figure 4:

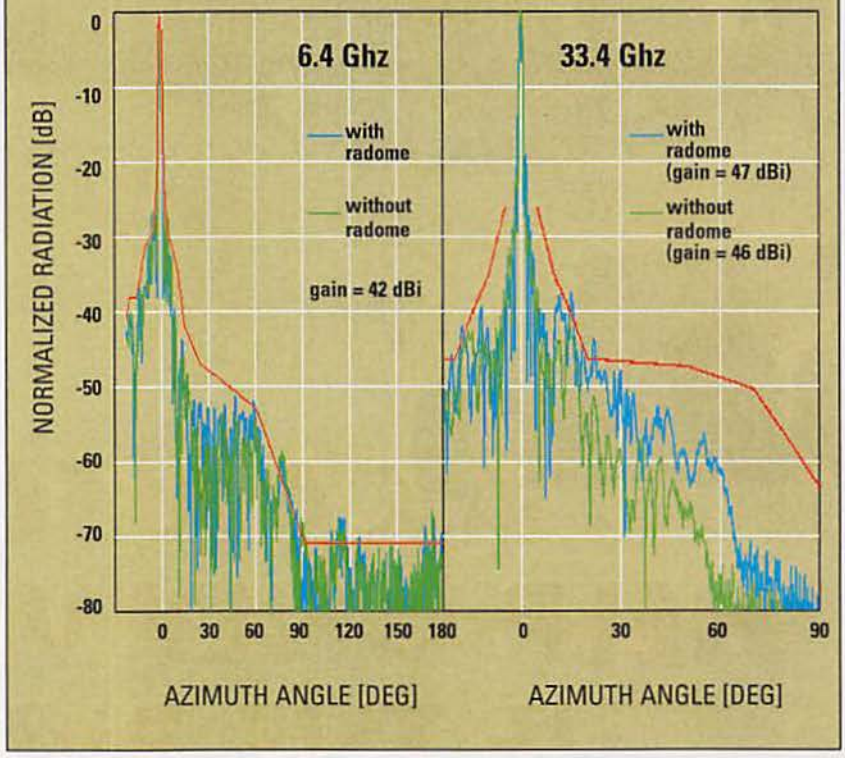

Figure 5: